Chemical mechanical polishing apparatus and method of chemical mechanical polishing

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Abstract

There is provided an apparatus for polishing a substrate, including (a) a polishing pad formed with a plurality of through-holes through which polishing material is supplied to a surface of the polishing pad, (b) a level block on which the polishing pad is mounted, and (c) a rotatable carrier for supporting a substrate thereon, the carrier being positioned in facing relation with the level block, the level block being rotatable around a rotation axis thereof with the rotation axis being moved along an arcuate path, and causing the polishing pad to make contact with the substrate for polishing the substrate, the polishing pad having a first ring-shaped region concentric thereto where no through-holes are formed. For instance, the first ring-shaped region has a width greater than 10%, but smaller than 95% of a radius of the polishing pad. The apparatus enhances uniformity in polishing a substrate.

Description

BACKGROUND OF THE INVENTION
[0002] 1. Field of the Invention
[0003] The invention relates to an apparatus for polishing a substrate for planarization by chemical mechanical polishing. The invention relates further to a method of chemical mechanical polishing.
[0004] 2. Description of the Related Art
[0005] FIGS. 1A to 1E illustrate respective steps in a method of forming a buried metal layer in a semiconductor device.
[0006] First, as illustrated in FIG. 1A, a semiconductor substrate 101 including active devices fabricated thereon is covered entirely with an insulating film 102.
[0007] Then, a resist film 105 having a certain pattern is formed on the insulating film 102, and subsequently, the insulating film 102 is etched with the patterned resist film 105 being used as a mask, to thereby form a contact hole 106 through the insulating film 102, as illustrated in FIG. 1B.
[0008] After removal of the resist film 105, as illustrated in FIG. 1C, a barrier film 103 composed of metal such as Ti or Ta is deposited over the insulating film 102 so that the contact hole 106 is covered at a sidewall and a bottom thereof with the barrier film 103.
[0009] Then, as illustrated in FIG. 1D, an electrically conductive layer 104 is deposited over the product to thereby fill the contact hole 106 with the electrically conductive layer 104.
[0010] Then, the electrically conductive film 104 is planarized by means of a chemical mechanical polishing apparatus 107, as illustrated in FIG. 1E. Thus, a buried metal layer 108 is formed.
[0011] The chemical mechanical polishing apparatus 107 includes a carrier on which a wafer to be polished is fixed, and a rotatable level block on which a polishing pad is mounted. A wafer is compressed onto a rotating polishing pad to thereby be polished. While a wafer is being polished by the polishing pad, polishing powder such as alumina or silica, and polishing slurry containing etchant such as H_2O_2 are

supplied between the polishing pad and the wafer.
[0012] FIG. 2 illustrates a conventional apparatus for polishing a wafer by chemical mechanical polishing. The illustrated apparatus is comprised of a level block 23 connected to a rotatable shaft 24, a polishing pad 29 fixed onto the level block 23, a wafer holder 26 connected to a rotatable shaft 27 and holding a wafer 25 on a bottom thereof, and a slurry source 30 supplying polishing slurry onto the polishing pad 29 through a slurry supply port 21.
[0013] The wafer 25 is sandwiched between the polishing pad 29 and the wafer holder 26. While the wafer 25 is being polished by the polishing pad 29, polishing slurry 22 is supplied between the polishing pad 29 and the wafer 25 around a periphery of the wafer 25.
[0014] Though the illustrated apparatus is designed to have one wafer holder 26, the apparatus may be designed to have a plurality of wafer holders 26. For instance, the apparatus may be designed to have four wafer holders 26 equally spaced from one another above the level block 23 in order to concurrently polish four wafers at a time.
[0015] A conventional apparatus for polishing a wafer, such as the apparatus illustrated in FIG. 2, is accompanied with a problem of non-uniformity in polishing speed in a wafer, which results in that a wafer is polished around a center thereof to a greater degree than a periphery thereof.
[0016] In order to overcome this problem, there has been suggested a first polishing apparatus in which a polishing pad mounted on a level block is formed with a plurality of small through-holes through which polishing slurry is supplied onto a surface of the polishing pad from a polishing slurry source. The small through-holes are positioned in concentration with an axis of the polishing pad 29. Since polishing slurry is uniformly supplied between a wafer and the polishing pad, it would be possible to keep a polishing speed constant to thereby enhance uniformity in polishing a wafer.
[0017] There has been suggested also a second polishing apparatus in which a polishing pad is composed of porous material in order to enhance uniformity in polishing a wafer.
[0018] However, since a wafer having a greater diameter is compressed onto a polishing pad at a greater pressure around a center thereof than a periphery thereof, a polished wafer would have a cross-section like a cross-section of a concave lens, if a wafer is polished in accordance with the above-mentioned first or second polishing apparatuses in which polishing slurry is uniformly supplied to a surface of a wafer, whereas a polished wafer would have a cross-section like a convex lens, if a wafer is polished in accordance with the apparatus illustrated in FIG. 2.
[0019] In order to avoid this problem, Japanese Unexamined Patent Publication No. 5-13389 has suggested a polishing apparatus which has the same structure as that of the above-mentioned first and second polishing apparatus, but is capable of controlling an amount of polishing slurry at a predetermined position of a polishing pad for the purpose of enhancing uniformity in polishing a wafer.
[0020] Specifically, the suggested polishing apparatus is formed with a plurality of through-holes through which polishing slurry is supplied onto a surface of a polishing pad, in such a manner that the number of through-holes per a unit area in a region closer to a center of a polishing pad is designed to be greater than the number of through-holes per a unit area in a region closer to a periphery of a polishing pad, or that a through-hole located closer to a center of a polishing pad is designed to have a greater diameter than a diameter of a through-hole located closer to a periphery of a polishing pad.
[0021] A diameter of a wafer necessary to be polished is increasing. For instance, a diameter of a wafer to be polished years ago was 6 inches (about 15 cm), but a diameter of a wafer to be polished presently is in the range of 8 to 10 inches (about 20 to about 25 cm). Such a wafer having a great diameter could not be polished by means of such an apparatus as illustrated in FIG. 2, because the level block 23 has to have too much area, which results in too high load to the apparatus.
[0022] Hence, there has been suggested such a polishing apparatus as illustrated in FIG. 3A, in order to avoid the above-mentioned problem. The illustrated apparatus is comprised of a rotatable carrier 2 supporting a wafer 1 at a bottom thereof, a level block 3, a polishing pad 4 mounted on the level block 3 and positioned in facing relation to the carrier 2, and a motor 5 for rotating the level block 3 around a rotation axis. The polishing pad 4 is formed with a plurality of through-holes equally spaced from one another.
[0023] The wafer 2 is made to rotate, and then, is compressed onto the rotating polishing pad 4. While the wafer 1 is being polished. While the wafer 2 is being polished, slurry 6 is supplied onto a surface of the polishing pad 4 through the through-holes.
[0024] In order to enhance uniformity in polishing the wafer 1, the level block 3 is rotated by means of the motor 5 in such a manner that the rotation axis of the level block 3 moves along an arcuate path. That is, the level block 3 makes so-called orbital revolution.
[0025] FIG. 4 shows a positional relation in orbital revolution between the wafer 1 rotating around a rotation axis A and the polishing pad 4 rotating around a rotation axis B. As illustrated in FIG. 4, if viewed from the rotation axis A, the rotation axis B rotates around the rotation axis A.

[0026] As mentioned earlier, if a wafer is polished with polishing slurry being supplied onto a surface of a polishing pad through through-holes formed with the polishing pad, there is caused a problem that a wafer is polished to a greater degree in a central region than in a peripheral region, resulting in that a wafer is concave in a central region thereof. If a wafer is non-uniformly polished as mentioned above, an electrically conductive film such as the electrically conductive film 104 illustrated in FIG. 1D partially remains non-removed on an insulating film such as the insulating film 102, resulting in current leakage between wirings.
[0027] In order to avoid such a problem, it is necessary to sufficiently polish a wafer. However, this may result in that a wiring to be formed on an insulating film has different heights above a central region and a peripheral region of a wafer. Accordingly, a wiring resistance above a central region of a wafer becomes different from a wiring resistance above a peripheral region of a wafer with the result of deterioration in electro-migration (EM).

SUMMARY OF THE INVENTION
[0028] It is an object of the present invention to provide an apparatus for polishing a wafer, which apparatus is capable of enhancing uniformity in polishing. It is also an object of the present invention to provide a method of doing the same.
[0029] The inventors had conducted a lot of experiments in order to accomplish the above-mentioned object, and had found out that if a polishing pad is designed to include a region where there are formed no through-holes through which polishing slurry is supplied to a surface of the polishing pad, it would be possible to enhance uniformity in polishing a wafer.
[0030] Specifically, in one aspect of the invention, there is provided an apparatus for polishing a substrate, including (a) a polishing pad formed with a plurality of through-holes through which polishing material is supplied to a surface of the polishing pad, (b) a level block on which the polishing pad is mounted, and (c) a rotatable carrier for supporting a substrate thereon, the carrier being positioned in facing relation with the level block, the level block being rotatable around a rotation axis thereof with the rotation axis being moved along an arcuate path, and causing the polishing pad to make contact with the substrate for polishing the substrate, the polishing pad having a first ring-shaped region concentric thereto where no through-holes are formed.
[0031] It is preferable that the first ring-shaped region has a width equal to or greater than 10%, more preferably 20%, of a radius of the polishing pad.
[0032] It is preferable that the through-holes are positioned in alignment with a peripheral region of the substrate when an axis of the level block is in alignment with an axis of the carrier.
[0033] It is preferable that the through-holes are positioned in a second ring-shaped region having an outer periphery common to an outer periphery of the polishing pad and having a width equal to 5% or smaller of a radius of the polishing pad.
[0034] It is preferable that the polishing pad includes a circular region concentric to the polishing pad and located inside the first ring-shaped region, and a third ring-shaped region located outside the first ring-shaped region, the circular region and the third ring-shaped region including the through-holes therein. In this arrangement, it is preferable that the third ring-shaped region has an outer periphery common to an outer periphery of the polishing pad. It is also preferable that the through-holes formed in the third ring-shaped region are positioned in alignment with a peripheral region of the substrate when an axis of the level block is in alignment with an axis of the carrier.
[0035] It is preferable that a total area of the through-holes varies in a radius-wise direction of the, polishing pad. For instance, the number of the through-holes per a unit area may be designed to decrease in a direction from an outer periphery to a center of the polishing pad. As an alternative, diameters of the through-holes may be designed to decrease in a direction from an outer periphery to a center of the polishing pad.
[0036] There is further provided an apparatus for polishing a substrate, including (a) a polishing pad formed with a plurality of through-holes through which polishing material is supplied to a surface of the polishing pad, (b) a level block on which the polishing pad is mounted, and (c) a rotatable carrier for supporting a substrate thereon, the carrier being positioned in facing relation with the level block, the level block being rotatable around a rotation axis thereof with the rotation axis being moved along an arcuate path, and causing the polishing pad to make contact with the substrate for polishing the substrate, the polishing pad having a circular region concentric thereto where no through-holes are formed.
[0037] It is preferable that the circular region has a radius equal to or smaller than 95% of a radius of the polishing pad.
[0038] It is preferable that the circular region has a radius equal to or greater than 30% of a radius of the polishing pad.
[0039] In another aspect of the present invention, there is provided a method of carrying out chemical mechanical polishing to a substrate, including the steps of (a) rotating a level block on which a polishing

pad is mounted, relative to a carrier on which a substrate is mounted, around a rotation axis thereof with the rotation axis being moved along an arcuate path, and (b) supplying polishing material on a surface of the polishing pad while the substrate is being polished by the polishing pad, in a region other than a first ring-shaped region concentric to the polishing pad.
[0040] For instance, the polishing material may be supplied on a surface of the polishing pad through through-holes formed with the polishing pad.
[0041] It is preferable that the polishing material is supplied on a surface of the polishing pad in a second ring-shaped region having an outer periphery common to an outer periphery of the polishing pad and having a width equal to 5% or smaller of a radius of the polishing pad.
[0042] It is preferable that the polishing pad includes a circular region concentric to the polishing pad and located inside the first ring-shaped region, and a third ring-shaped region located outside the first ring-shaped region, the polishing material being supplied into the circular region and the third ring-shaped region.
[0043] It is preferable that the polishing material is supplied onto a surface of the polishing pad in a varying amount in a radius-wise direction of the polishing pad. For instance, the polishing material may be supplied in a greater amount in a region closer to a center of the polishing pad.
[0044] There is further provided a method of carrying out chemical mechanical polishing to a substrate, including the steps of (a) rotating a level block on which a polishing pad is mounted, relative to a carrier on which a substrate is mounted, around a rotation axis thereof with the rotation axis being moved along an arcuate path, and (b) supplying polishing material on a surface of the polishing pad while the substrate is being polished by the polishing pad, in a region other than a circular region concentric to the polishing pad.
[0045] It is preferable that the circular region has a radius equal to or smaller than 95% of a radius of the polishing pad.
[0046] It is preferable that the circular region has a radius equal to or greater than 30% of a radius of the polishing pad.
[0047] In the apparatus in accordance with the present invention, a polishing pad is designed to have a region in which through-holes through which polishing material is supplied to a surface of the polishing pad are not formed. In the method in accordance with the present invention, polishing material is supplied to a surface of a polishing pad in a region other than a certain region of the polishing pad. As a result, the present invention makes it possible to accomplish uniformity in polishing rate in a high degree. Hence, when a buried metal layer is to be formed by chemical mechanical polishing, a resultant semiconductor device could have superior resistance to electro-migration (EM).
[0048] The above and other objects and advantageous features of the present invention will be made apparent from the following description made with reference to the accompanying drawings, in which like reference characters designate the same or similar parts throughout the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS
[0049] FIGS. 1A to 1E are cross-sectional views of a semiconductor device, illustrating respective steps of a method of forming a buried metal layer by chemical mechanical polishing.
[0050] FIG. 2 illustrates a conventional apparatus for polishing a wafer.
[0051] FIG. 3A illustrates an apparatus for polishing a wafer, to which apparatus the present invention may be applied.
[0052] FIG. 3B is a plan view of a polishing pad employed in the apparatus illustrated in FIG. 3A.
[0053] FIG. 3C is a plan view of another polishing pad employed in the apparatus illustrated in FIG. 3A.
[0054] FIG. 4 illustrates a positional relation between two rotation axes in orbital revolution.
[0055] FIG. 5 is a graph showing a relation between uniformity in a polishing rate and a radius of a circular region in which through-holes are closed.
[0056] FIG. 6 is a graph showing a relation between uniformity in a polishing rate and a radius of a circular region in which through-holes are open.
[0057] FIG. 7 is a flow chart of a method of polishing a wafer.

DESCRIPTION OF THE PREFERRED EMBODIMENTS
[0058] FIG. 3A illustrates an apparatus for polishing a substrate, in accordance with the first embodiment of the present invention.
[0059] The illustrated apparatus is comprised of a polishing pad 4 formed with a plurality of through-holes (shown in phantom at 6A) through which polishing slurry 6 is supplied to a surface of the polishing pad 4, a level block 3 on which the polishing pad 4 is mounted, a motor 5 for rotating the level block 3 around a rotation axis, and a rotatable carrier 2 for supporting a wafer 1 at a bottom surface thereof in facing relation with the polishing pad 4.
[0060] Though the wafer 1 is rotated around a stationary rotation axis 1A thereof, the polishing pad 4

makes orbital revolution around the rotation axis 1A of the wafer 1. Specifically, the level block 3 and hence the polishing pad 4 are rotated around a rotation axis 3A thereof, and, at the same time, the rotation axis 3A is moved along an arcuate path. That is, as illustrated in FIG. 4, if viewed from the rotation axis 1A, the rotation axis 3A rotates around the rotation axis 1A.
[0061] The wafer 1 is compressed onto the polishing pad 4 to thereby be polished.
[0062] The polishing pad 4 is designed to have a first ring-shaped region 4a which is concentric to a center 4b of the polishing pad 4, as illustrated in FIG. 3B. The through-holes through which the polishing slurry 6 is supplied to a surface of the polishing pad 4 are formed in a region, other than the first ring-shaped region 4a, namely, in both a circular region 4c located inside the first ring-shaped region 4a and a ring-shaped region 4d located outside the first ring-shaped region 4a, whereas no through-holes are formed in the first ring-shaped region 4a.
[0063] The apparatus in accordance with the first embodiment includes the polishing pad 4 which is designed to have the first ring-shaped region 4a where there are formed no through-holes through which the polishing slurry 6 is supplied to a surface of the polishing pad 4. The wafer 1 is certainly polished in the first ring-shaped region 4a, resulting in a polishing condition where high uniformity in a polishing rate is established.
[0064] It is preferable that the first ring-shaped region 4a has a width equal to or greater than 10% of a radius of the polishing pad 4 for accomplishing sufficient uniformity in a polishing rate. It is more preferable that the first ring-shaped region 4a has a width equal to or greater than 20% of a radius of the polishing pad 4.
[0065] It is also preferable that the polishing pad 4 is formed at a peripheral region thereof with the through-holes. It is more preferable that the through-holes are formed in the polishing pad 4 in alignment with a peripheral region of the wafer 1, when the axis 3A of the polishing pad 4 is in alignment with the axis 1A of the wafer 1.
[0066] The polishing pad 4 may be designed to be formed with the through-holes in a central region thereof, or may be designed to be formed with no through-holes in a central region thereof. If no through-holes are formed in a central region of the polishing pad 4, it is preferable that no through-holes are formed in a circular region outwardly radially extending from a center of the polishing pad 4 and having a radius equal to or greater than 30% of a radius of the polishing pad 4.
[0067] When hard material is to be polished, it is preferable that the through-holes are formed in a central region of the polishing pad 4, which ensures higher uniformity in a polishing rate.
[0068] In later mentioned examples, there was conducted an experiment in which the through-holes are closed. However, in practical use, the through-holes are formed in a polishing pad in predetermined positions.
[0069] It is not always necessary to uniformly position the through-holes in a surface of the polishing pad 4. A total area of the through-holes may be designed to vary in a radius-wise direction of the polishing pad 4. For instance, the number of the through-holes per a unit area may be designed to decrease in a direction from an outer periphery to a center of the polishing pad 4. As an alternative, the through-holes may be designed to have a decreasing diameter in a direction from an outer periphery to a center of the polishing pad 4.
[0070] Hereinbelow are explained the experiments in which a wafer was polished by means of the apparatus in accordance with the above-mentioned embodiment.

EXAMPLE 1
[0071] As a wafer to be polished, there was used a wafer which had a diameter of 8 inches (about 20 cm) and on which metal films composed of Cu. Ta, and TiN were formed. The wafer was polished by means of the apparatus illustrated in FIG. 3A. A polishing pad was formed uniformly with the through-holes, and had a diameter of 10 inches (about 25 cm).
[0072] The wafer was polished with the through-holes located closer to a center of the polishing pad, being closed one by one.
[0073] FIG. 5 shows uniformity in a polishing rate in this experiment. The uniformity was estimated with 3 [sigma] (%). The polishing conditions were as follows.
[0074] Pressure: 3 psi
[0075] r.p.m.: 260/16
[0076] Polishing slurry supply: 100 cc/minute
[0077] The polishing slurry having been employed in this experiment was commercially available one.
[0078] As is obvious in view of FIG. 5, the uniformity represented by 3[sigma] is equal to or smaller than 15%, if the polishing pad had a circular region in which no though-holes are formed and which is concentric to a center of the polishing pad and has a diameter in the range of 1.5 inches to 4.7 inches. In particular, there is obtained high uniformity equal to or smaller than 10%, if the wafer had a diameter in the range of 2

inches to 4.5 inches.
[0079] Thus, it is understood from these results that high uniformity in a polishing rate can be obtained, if a region 4e where no through-holes are formed is formed as a circular region concentric to the polishing pad and having a radius equal to or smaller than 95% of a radius of the polishing pad, as illustrated in FIG. 3C.
[0080] In addition, it is also understood that it is preferable that the region 4e has a radius equal to or greater than 30% of a radius of the polishing pad, as illustrated in FIG. 3C.
[0081] In brief, the region 4e where no through-holes are formed preferably has a radius equal to or smaller than 0.95R, but equal to or greater than 0.3R where R indicates a radius of the polishing pad 4.
[0082] In particular, high uniformity in a polishing rate can be obtained in a 8-inch wafer having been employed in the experiment, if no through-holes are formed in the polishing pad within a circular region concentric to a center of the polishing pad and having a radius of 4 inches, which is equal to a radius of the 8-inch wafer, when a rotation axis of the polishing pad is in alignment with a rotation axis of the wafer.
[0083] Then, rates of polishing Ta and TiN both of which are generally used as material of which a barrier film is composed were also estimated. In the experiment for estimating the polishing rates, the through-holes of the polishing pad were all closed in a circular region concentric to a center of the polishing pad and having a radius of 4 inches, and then, the through-hole located closer to a center of the polishing pad was made open one by one. Uniformity in a polishing rate, represented by 3[sigma], was estimated in the same manner as the above-mentioned estimation.
[0084] FIG. 6 shows the results of the experiment. As is understood in view of FIG. 6, uniformity of 15% or smaller can be obtained, even if the through-holes are made open in a circular region concentric to the polishing pad and having a radius of 3.5 inches. That is, if the polishing pad is designed to have a region where no through-holes are formed, which region has a width of 0.5 inches or greater, sufficient uniformity in a polishing rate can be obtained. Herein, 0.5 inches correspond to 10% of a radius of the polishing pad.
[0085] There is a slight dispersion in uniformity in a polishing rate in dependence on material of which the polishing pad is composed. For instance, when a film composed of Ta harder than TiN is to be polished, it is optimal that the through-holes are formed in a circular region concentric to a center of the polishing pad and having a radius in the range of 1.0 to 1.5 inches.

EXAMPLE 2
[0086] A semiconductor device was fabricated in accordance with the steps illustrated in FIGS. 1A to 1E.
[0087] First, as illustrated in FIG. 1A, a semiconductor substrate 101 including active devices fabricated thereon is covered entirely with an insulating film 102.
[0088] Then, a resist film 105 having a certain pattern is formed on the insulating film 102, and subsequently, the insulating film 102 is etched with the patterned resist film 105 being used as a mask, to thereby form a contact hole 106 through the insulating film 102, as illustrated in FIG. 1B.
[0089] After removal of the resist film 105, as illustrated in FIG. 1C, a barrier film 103 composed of metal such as Ti or Ta is deposited over the insulating film 102 so that the contact hole 106 is covered at a sidewall and a bottom thereof with the barrier film 103.
[0090] Then, as illustrated in FIG. 1D, an electrically conductive layer 104 composed of copper is deposited over the barrier film 103 to thereby fill the contact hole 106 with the electrically conductive layer 104.
[0091] Then, the electrically conductive film 104 is planarized by means of a chemical mechanical polishing apparatus 107, as illustrated in FIG. 1E. Thus, a buried metal layer 108 is formed.
[0092] In Example 2, the polishing apparatus illustrated in FIG. 3A was used as the chemical mechanical polishing apparatus 107. A wafer to which the steps having been explained with reference to FIGS. 1A to 1D had been carried out was polished by means of the polishing apparatus in the following conditions.
[0093] Polishing pressure: 3 psi
[0094] r.p.m.: 260/16
[0095] Polishing slurry supply: 100 cc/minute
[0096] The polishing slurry having been employed in this experiment was commercially available. The polishing pad having been employed in this experiment was designed to have a circular region concentric thereto and having a radius of 4 inches.
[0097] The thus fabricated semiconductor device was estimated with respect to resistance to electro-migration (EM). There was obtained quite high EM-resistance.
[0098] FIG. 7 is a flow chart of a method in accordance with the present invention.
[0099] Hereinbelow is explained the method in the assumption that the method is carried out through the use of the polishing apparatus illustrated in FIG. 3A.
[0100] First, in step S1, the level block 3 and hence the polishing pad 4 are made to carry out orbital revolution relative to the wafer 1 supported at a bottom of the carrier 2. Specifically, the polishing pad 4 is rotated around the rotation axis 3A, and at the same time, the rotation axis 3A is rotated around the rotation axis 1A of the wafer 1 in such a manner as illustrated in FIG. 4.

[0101] Then, in step S2, the polishing slurry 6 is supplied onto a surface of the polishing pad 4 while the wafer 1 is being polished by the polishing pad 4, only in a region other than the ring-shaped region 4a concentric to the polishing pad 4.
[0102] Thus, the wafer 1 is polished with uniformity in a polishing rate, in step 3.
[0103] The above-mentioned method provides the same advantages as those obtained by the polishing apparatus in accordance with the above-mentioned embodiment.
[0104] In the above-mentioned method, the polishing pad 4 may be designed to be formed with a circular region where no through-holes are formed, such as the circular region 4e illustrated in FIG. 3C, in place of the ring-shaped region 4a.
[0105] While the present invention has been described in connection with certain preferred embodiments, it is to be understood that the subject matter encompassed by way of the present invention is not to be limited to those specific embodiments. On the contrary, it is intended for the subject matter of the invention to include all alternatives, modifications and equivalents as can be included within the spirit and scope of the following claims.
[0106] The entire disclosure of Japanese Patent Application No. 10-45372 filed on Feb. 26, 1998 including specification, claims, drawings and summary is incorporated herein by reference in its entirety.

Claims

1. An apparatus for polishing a substrate, comprising:
(a) a polishing pad formed with a plurality of through-holes through which polishing material is supplied to a surface of said pad;
(b) a level block on which said polishing pad is mounted; and
(c) a rotatable carrier for supporting a substrate thereon, said carrier being positioned in facing relation with said level block;
said level block being rotatable around a rotation axis thereof with said rotation axis being moved along an arcuate path, and causing said polishing pad to make contact with said substrate for polishing said substrate,
said polishing pad having a first ring-shaped region concentric thereto where no through-holes through which polishing material is supplied are formed.

2. The apparatus as set forth in claim 1, wherein said first ring-shaped region has a width equal to or greater than 10% of a radius of said polishing pad.

3. The apparatus as set forth in claim 2, wherein said first ring-shaped region has a width equal to or greater than 20% of a radius of said polishing pad.

4. The apparatus as set forth in claim 1, wherein said through-holes are positioned in alignment with a peripheral region of said substrate when an axis of said level block is in alignment with an axis of said carrier.

5. The apparatus as set forth in claim 1, wherein said through-holes are positioned in a second ring-shaped region having an outer periphery common to an outer periphery of said polishing pad and having a width equal to 5% or smaller of a radius of said polishing pad.

6. The apparatus as set forth in claim 1, wherein said polishing pad includes a circular region concentric to said polishing pad and located inside said first ring-shaped region, and a third ring-shaped region located outside said first ring-shaped region, said circular region and said third ring-shaped region including said through-holes therein.

7. The apparatus as set forth in claim 6, wherein said third ring-shaped region has an outer periphery common to an outer periphery of said polishing pad.

8. The apparatus as set forth in claim 6, wherein said through-holes formed in said third ring-shaped region are positioned in alignment with a peripheral region of said substrate when an axis of said level block is in alignment with an axis of said carrier.

9. The apparatus as set forth in claim 1, wherein a total area of said through-holes varies in a radius-wise direction of said polishing pad.

10. The apparatus as set forth in claim 9, wherein the number of said through-holes per a unit area decreases in a direction from an outer periphery to a center of said polishing pad.

11. The apparatus as set forth in claim 9, wherein diameters of said through-holes decrease in a direction from an outer periphery to a center of said polishing pad.

12. An apparatus for polishing a substrate, comprising:
(a) a polishing pad formed with a plurality of through-holes through which polishing material is supplied to a surface of said polishing pad;
(b) a level block on which said polishing pad is mounted; and
(c) a rotatable carrier for supporting a substrate thereon, said carrier being positioned in facing relation with said level block;
said level block being rotatable around a rotation axis thereof with said rotation axis being moved along an arcuate path, and causing said polishing pad to make contact with said substrate for polishing said substrate,
said polishing pad having a circular region concentric thereto where no through-holes through which polishing material is supplied are formed.

13. The apparatus as set forth in claim 12, wherein said circular region has a radius equal to or smaller than 95% of a radius of said polishing pad.

14. The apparatus as set forth in claim 12, wherein said circular region has a radius equal to or greater than 30% of a radius of said polishing pad.

15. The apparatus as set forth in claim 12, wherein said through-holes are positioned in alignment with a peripheral region of said substrate when an axis of said level block is in alignment with an axis of said carrier.

16. The apparatus as set forth in claim 12, wherein said through-holes are positioned in a ring-shaped region having an outer periphery common to an outer periphery of said polishing pad and having a width equal to 5% or smaller of a radius of said polishing pad.

17. The apparatus as set forth in claim 12, wherein a total area of said through-holes varies in a radius-wise direction of said polishing pad.

18. The apparatus as set forth in claim 17, wherein the number of said through-holes per a unit area decreases in a direction from an outer periphery to a center of said polishing pad.

19. The apparatus as set forth in claim 17, wherein diameters of said through-holes decrease in a direction from an outer periphery to a center of said polishing pad.

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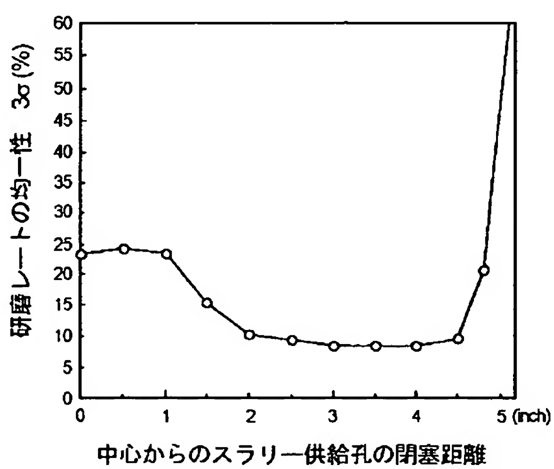
(54)【発明の名称】　研磨装置及び該装置を用いる半導体装置の製造方法

(57)【要約】

【課題】　ウエハを保持するキャリアに対して研磨パッドを保持する研磨定盤がオービタル回転する枚葉型の研磨装置において、研磨の均一性を高めることの可能な研磨装置を提供する

【解決手段】　研磨パッドが、その中心から外周に向かって同心円状に所定の幅、例えば、半径５インチの研磨パッドでは中心から１．５インチ以上、４．７５インチ以下の幅でスラリー供給孔の無い領域を有することを特徴とする。



【特許請求の範囲】
【請求項１】　表面に研磨パッドを備え、該研磨パッドに設けられた複数のスラリー供給孔から所定量の研磨スラリーを供給可能な研磨定盤と、該研磨定盤に対向し一枚の被研磨基板を保持するキャリア、とを有する化学的機械研磨法による研磨装置であって、前記研磨定盤は前記キャリア面よりも大きな研磨面を有し、その中心軸が円弧状に移動しながら回転するものであって、回転する前記キャリアと当接させて被研磨基板の研磨を行う研磨装置において、
前記研磨パッドは、その中心から外周に向かって同心円状に所定の幅でスラリー供給孔の無い領域を有することを特徴とする研磨装置。
【請求項２】　前記スラリー供給孔の無い領域が研磨パッドの半径の１０％以上の幅であることを特徴とする請求項１に記載の研磨装置。
【請求項３】　前記研磨パッドの中心から半径の３０％までの領域にスラリー供給孔のない領域を有することを特徴とする請求項１又は２に記載の研磨装置。
【請求項４】　前記研磨定盤とキャリアとの中心軸を合わせた際に、スラリー供給孔が被研磨基板の外周に配されていることを特徴とする請求項３に記載の研磨装置。
【請求項５】　前記研磨パッドの中心部及び周辺部にスラリー供給孔が配されており、その間にスラリー供給孔の無い領域を有することを特徴とする請求項１又は２に記載の研磨装置。
【請求項６】　前記研磨定盤とキャリアとの中心軸を合わせた際に、前記研磨パッドの周辺部に設けられるスラリー供給孔が被研磨基板の外周に配されていることを特徴とする請求項５に記載の研磨装置。
【請求項７】　能動素子を有した半導体基板に絶縁膜層を形成する工程、該絶縁膜層をエッチングしてコンタクトホールを形成する工程、形成されたコンタクトホールの壁面及び底を埋めるようにバリア膜を形成する工程、導電性材料を成膜しコンタクトホールを埋める工程、及び化学的機械研磨法により膜表面の平坦化を行い、埋め込み配線を形成する工程とを含んでなる半導体装置の製造方法において、前記化学的機械研磨を請求項１～６のいずれか１項に記載の研磨装置を用いることを特徴とする半導体装置の製造方法。
【発明の詳細な説明】
【０００１】
【発明の属する技術分野】本発明は、化学的機械研磨法（Chemical Mechanical Polishing、以下「ＣＭＰ」と略す）により基板を研磨して平坦化する研磨装置に関する。また、この研磨装置を用いた半導体装置の製造方法にも関する。
【０００２】
【従来の技術】従来、半導体装置、特に埋め込み金属配線を製造するには、例えば、図５に示すように、能動素子を有した半導体基板１１に絶縁膜層１２を形成し（図５（ａ））、該絶縁膜層１２上にレジストパターン１５を形成し、これをマスクに絶縁膜層１２をエッチングしてコンタクトホール１６を形成する（図５（ｂ））。形成されたコンタクトホール１６の壁面及び底を埋めるようにＴｉやＴａなどのバリア膜１３を形成した後（図５（ｃ））、導電性材料１４を成膜しコンタクトホール１６を埋める（図５（ｄ））。続いてＣＭＰにより膜表面の平坦化を行い、埋め込み配線を形成する（図５（ｅ））。
【０００３】ＣＭＰには、アルミナやシリカ等の研磨粒子と、過酸化水素水等のエッチャントを含有する研磨スラリーを供給しながら、キャリアに固定されたウエハを研磨パッドを貼った回転する研磨定盤に押し当てて行う。
【０００４】従来の研磨装置としては、図６に示すように、回転する研磨定盤回転軸２４に支承され、研磨パッド２９を備えた研磨定盤２３上にウエハ２５をセットし、研磨スラリー２２をスラリー供給系３０からスラリー供給口２１を介してウエハ２５の周辺から供給しながら、研磨する装置が知られている。尚、図では研磨定盤に対してウエハ支持台回転軸２７に支承された一つのウエハ支持台２６を有する構成を示しているが、支持台２６は複数であっても良く、例えば、一度に４枚のウエハを同時に処理するよう研磨定盤上に均等に４つのウエハ支持台２６を有する構成のものもある。
【０００５】従来のこのような装置では、ウエハ中心よりもウエハ周辺でより研磨が成されるというウエハ内の研磨速度の不均一性が問題となっていた。この問題を解消するために、スラリー供給系から供給されるスラリーを研磨定盤２３上の研磨パッド２９に同心円状に穿った複数の小孔（スラリー供給孔）を通してウエハ表面にほぼ均等に供給しながらその表面を研磨することによって、研磨速度を一定にして研磨の均一性を向上させることが提案されている。或いは、研磨パッドを多孔質で連続孔を有する材料で形成して、ウエハ面の研磨の均一性を向上させる試みも為されている。
【０００６】しかしながらウエハの直径が大きくなると、ウエハが研磨パッドに押し付けられる圧力はウエハ周辺よりも中心のほうが大きくなるため、スラリーをウエハ面に均一に供給する上記の方法では、研磨後の断面形状が従来の凸レンズ状から凹レンズ状になることが予想される。そこで、特開平５－１３３８９号公報では、上記構成の研磨装置において、前記研磨パッドの表面へのスラリー供給量を研磨パッドの所定位置にてコントロール可能にし、ウエハ面内の均一性を更に高める方法が提案されている。具体的には、スラリー供給孔を研磨定盤の中心部ほど粗に構成し、周辺部ほど密に構成する、或いはスラリー供給孔の直径を研磨定盤の中心部ほど小さく、周辺部で大きくなるように構成した例が示されて

いる。
【0007】一方、研磨されるウエハサイズは、年々更に大きくなる傾向にあり、6インチ（約15cm）から、更には8～10インチ（約20～25cm）のものが主流になりつつある。このように大型化されたウエハの研磨には、前記図6に示すような研磨装置では、研磨定盤の面積が広くなりすぎ、装置負荷が高くなるために使用できない。そこで、図3に示すような枚葉型の研磨装置が用いられる。図3では一定方向に自転するウエハ1を装着したキャリア2と、研磨パッド4の装着された研磨定盤3とを当接させて研磨を行うものである。この時、研磨の均一性を高めるために、研磨定盤3はモーター5を駆動させることによりその回転軸が円弧を描くように移動しながら回転させる、いわゆるオービタル回転させるのが一般的である。この時、スラリー6は研磨定盤3の研磨パッド4全面に均等の間隔で穿たれたスラリー供給孔を介して供給される。
【0008】ここで、オービタル回転について更に説明すると、回転軸Aを中心に自転するヘッド上部（ウエハ側）と回転軸Bを中心に自転するヘッド下部（パッド側）とは図4に示すような位置関係で変化する。つまり、軸Aを中心に見た場合、軸Bは軸Aの周りを回転しながら、移動している。
【0009】
【発明が解決しようとする課題】このように研磨パッドの全面に均等に穿たれたスラリー供給孔を介してスラリーを供給しながら研磨を実施すると、ウエハ中心部が周辺部よりも多く研磨され、ウエハ中央部が窪んだ状態となるという欠点がある。このように研磨が均一に実施されない場合、ある部分で絶縁膜上に導電性膜が残り配線間リーク等の原因となる。これをなくすためには十分に研磨する必要があり、その結果、ウエハの中央部と周辺部とでは配線高さが大きく変わり、配線抵抗が異なることとなり、EM（エレクトロマイグレーション）耐性が悪くなる。
【0010】よって、本発明の目的は、ウエハを保持するキャリアに対して研磨パッドを保持する研磨定盤がオービタル回転する枚葉型の研磨装置において、研磨の均一性を高めることの可能な研磨装置を提供することにある。
【0011】
【課題を解決するための手段】本発明者らは、上記の課題を解決するべく鋭意検討した結果、研磨パッドを介して研磨スラリーを供給する装置において、研磨パッドにスラリー供給孔がある幅で設けられていない領域を有する場合に、研磨速度の均一性が向上することを見出した。
【0012】すなわち本発明は、表面に研磨パッドを備え、該研磨パッドに設けられた複数のスラリー供給孔から所定量の研磨スラリーを供給可能な研磨定盤と、該研磨定盤に対向し一枚の被研磨基板を保持するキャリア、とを有する化学的機械研磨法による研磨装置であって、前記研磨定盤は前記キャリア面よりも大きな研磨面を有し、その中心軸が円弧状に移動しながら回転するものであって、回転する前記キャリアと当接させて被研磨基板の研磨を行う研磨装置において、前記研磨パッドは、その中心から外周に向かって同心円状に所定の幅でスラリー供給孔の無い領域を有することを特徴とする研磨装置に関する。
【0013】
【発明の実施の形態】本発明では、所定の幅のスラリー供給孔の無い領域を有する研磨パッドを使用することで、その領域で確実に研磨が実行され、研磨速度の均一性の極めて高い研磨面を得ることができる。
【0014】スラリー供給孔の無い領域の幅としては、半径の10％以上であれば十分な研磨速度の均一性が得られるが、より好ましくは半径の20％以上であるのが望ましい。また、パッドの外周にはスラリー供給孔を設けるのが望ましく、少なくとも外周から中心に向かって半径の5％の範囲、より好ましくは、研磨定盤とキャリアとの中心軸を合わせた際に、スラリー供給孔が被研磨基板の外周に配されているように設けるのが望ましい。
【0015】研磨パッドの中央部にはスラリー供給孔を設けない構成、或いは設ける構成のどちらでも実施できるが、中央部にスラリー供給孔を設けない場合には、中心から外周に向かって半径の少なくとも30％までスラリー供給孔の無い領域を設けるのが望ましい。また、硬い材料を研磨する場合には中央部にスラリー供給孔を設けるほうが、より高い研磨速度の均一性が得られることから望ましい。
【0016】尚、後述する実施例では全面に均等に穿ったスラリー供給孔を埋めて実験を行っているが、実際の使用に際しては、スラリー供給孔の無い研磨パッドに所定の位置にスラリー供給孔を形成して使用するのが望ましい。そうすることにより、より研磨速度の均一性がより向上する。
【0017】尚、スラリー供給孔は均等に設ける必要は必ずしも無く、例えば、研磨パッドの外周側では大きな径のスラリー供給孔を設け、中央部に向かって徐々にスラリー供給孔の径を小さくする構成や、研磨パッドの外周から中央に向かって徐々にスラリー供給孔の密度を変えるなどして、供給するスラリー量を変化させても良い。
【0018】
【実施例】以下、実施例により本発明を説明するが、本発明はこれらの実施例のみに限定されるものではない。
【0019】実施例1
8インチ（約20cm）のウエハ上に金属膜（Cu，Ta，TiN）を全面に成膜したものを研磨試料として、図3に示す枚葉型研磨装置にセットして研磨を行った。

この時、全面に均等の間隔でスラリー供給孔を有するパッド（直径１０インチ（約２５ｃｍ））のスラリー供給孔を中心から徐々に閉塞しながら研磨を実施した。この時の研磨速度の均一性（３σ（％）で評価）を図１に示す。尚、研磨条件としては、圧力３ｐｓｉ、回転数２６０／１６ｒｐｍ、スラリー供給量１００ｃｃ／分で実施した。また、研磨スラリーとしては、市販のものを使用した。

【００２０】同図から明らかなように、１．５～４．７インチの間で３σが１５％以下であり、特に２～４．５インチでは１０％以下という優れた均一性が得られた。

【００２１】この結果から、パッドの中心から外周に向かって半径の９５％以下の範囲でスラリー供給孔の無い領域を設けると優れた研磨速度の均一性が得られることが分かる。また、少なくとも中心から半径方向に３０％までの範囲にはスラリー供給孔を設けないことが好ましいことが分かる。特にこの実施例で使用した８インチウエハの場合、研磨パッドとウエハの中心を合わせた際にスラリー供給孔がウエハの外周である半径４インチまで研磨パッドにスラリー供給孔を設けない場合に効果が大きい。次に、バリア膜材料として一般的に使用されているＴａ，ＴｉＮの研磨速度について評価した。この時、研磨パッドの中心から４インチまでスラリー供給孔を閉塞した状態から、中心から徐々にスラリー供給孔を開口していき、研磨速度の均一性（３σ）を同様に評価した。この結果を図２に示す。同図から分かるように、中心から半径方向に３．５インチまで開口させても１５％以下の均一性が得られている。つまり、この例では０．５インチ（パッドの半径方向の１０％）以上の幅でスラリー供給孔の無い領域を有していれば、十分な研磨速度の均一性が得られることが分かる。また、材料によっては多少の研磨速度の均一性に違いがあり、ＴｉＮよりも硬いＴａでは、パッド中心から１～１．５インチの範囲まで開口を設けたものが最適となるという結果を得ている。

【００２２】実施例２

図５に示す工程にしたがって、半導体装置を形成した。能動素子を有した半導体基板１０１に絶縁膜層１０２を形成し（図５（ａ））、該絶縁膜層１０２上にレジストパターン１０５を形成し、これをマスクに絶縁膜層１０２を公知の方法でエッチングしてコンタクトホール１０６を形成する（図５（ｂ））。形成されたコンタクトホール１０６の壁面及び底を埋めるようにＴｉやＴａなどのバリア膜１０３を形成した後（図５（ｃ））、銅膜１０４をＣＶＤ法で成膜しコンタクトホール１０６を埋める（図５（ｄ））。続いてＣＭＰにより膜表面の平坦化を行い、埋め込み配線を形成する（図５（ｅ））。

【００２３】ＣＭＰは、図３に示す研磨装置に図５（ｄ）の工程まで実施したウエハ（径８インチ）を設置し、研磨圧力３ｐｓｉ、回転数２６０／１６ｒｐｍ、スラリー供給量１００ｃｃ／分で実施した。また、研磨スラリーとしては、市販のものを使用した。尚、研磨パッドには中心から半径４インチまでスラリー供給孔を設けていないものを使用した。

【００２４】このようにして形成した半導体装置のＥＭ耐性を評価したところ、極めて良好な結果が得られた。

【００２５】

【発明の効果】以上説明したように、本発明によれば、枚葉型の研磨装置において、研磨パッドにスラリー供給孔が所定の幅で設けられていないものを使用することで、きわめて高い水準で研磨速度の均一性を達成することが可能となり、ＣＭＰによる配線埋め込みを実施した場合には、ＥＭ耐性の優れた半導体装置を提供することが可能となる。

【図面の簡単な説明】

【図１】研磨パッドの中心からのスラリー供給孔の閉塞距離に対する研磨のばらつきを示すグラフである。

【図２】研磨パッドの中心からスラリー供給孔を徐々に開口していった場合の研磨のばらつきを示すグラフである。

【図３】枚葉型の研磨装置の概略構成図である。

【図４】オービタル回転を説明する図である。

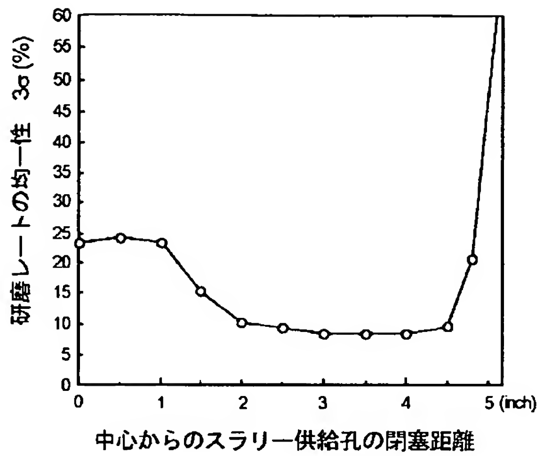
【図５】ＣＭＰにより埋め込み配線を形成する工程を示す工程断面図である。

【図６】従来の研磨装置の概略構成図である。

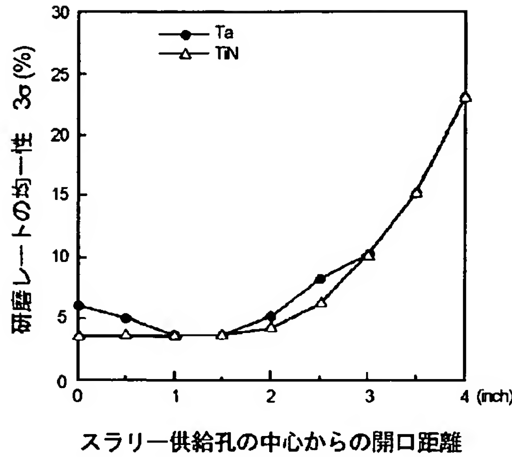
【符号の説明】

１　ウエハ
２　キャリア
３　研磨定盤
４　研磨パッド
５　モーター
６　スラリー

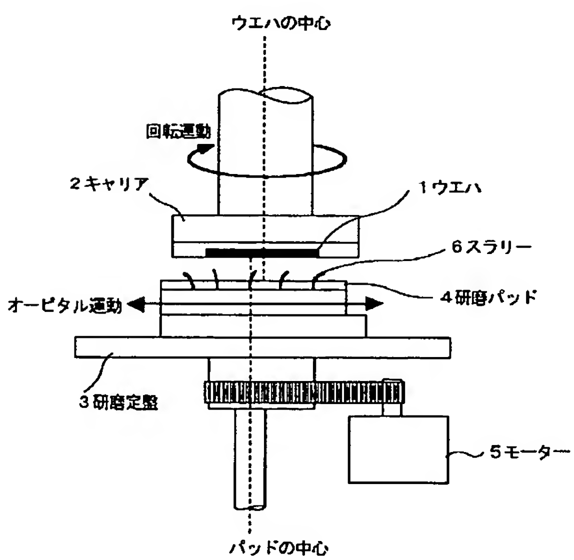
【図1】


研磨レートの均一性 3σ (%)
60
55
50
45
40
35
30
25
20
15
10
5
0
0
1
2
3
4
5 (inch)
中心からのスラリー供給孔の閉塞距離

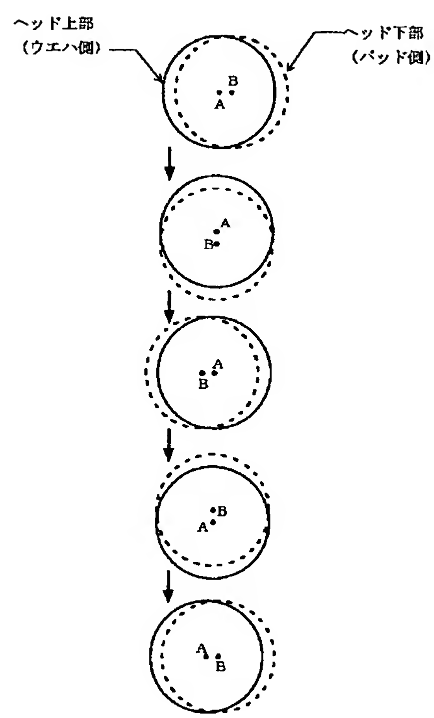
【図2】


Ta
TiN
研磨レートの均一性 3σ (%)
30
25
20
15
10
5
0
0
1
2
3
4 (inch)
スラリー供給孔の中心からの開口距離

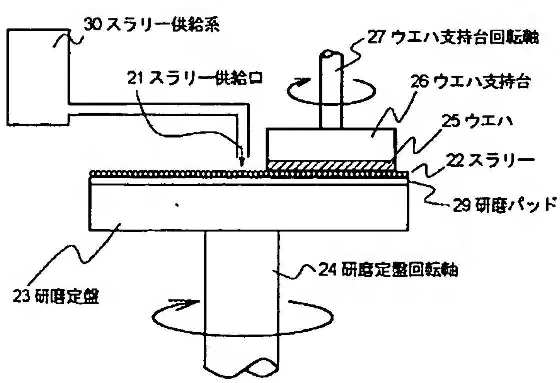
【図3】


ウエハの中心
回転運動
2キャリア
1ウエハ
6スラリー
オービタル運動
4研磨パッド
3研磨定盤
5モーター
パッドの中心

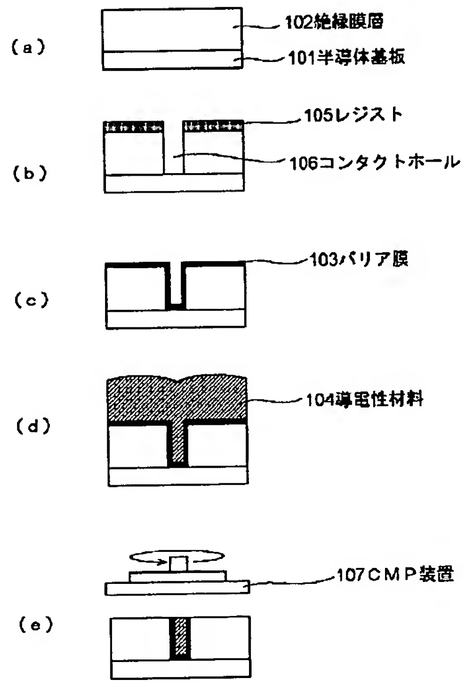
【図4】


ヘッド上部
(ウエハ側)
ヘッド下部
(パッド側)
A
B

【図6】


30スラリー供給系
21スラリー供給口
27ウエハ支持台回転軸
26ウエハ支持台
25ウエハ
22スラリー
29研磨パッド
23研磨定盤
24研磨定盤回転軸

【図５】


(a)
102絶縁膜層
101半導体基板
(b)
105レジスト
106コンタクトホール
(c)
103バリア膜
(d)
104導電性材料
(e)
107ＣＭＰ装置